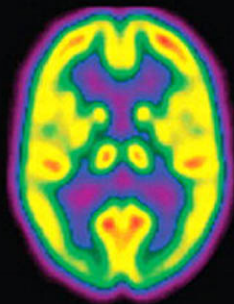


PICTURES

of THE

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What the New Neuroscience Tells Us About Who We Are



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Introduction

Imagine your mind is a yard on a clear March day. You've been offered a chance to walk around. You may choose to clear fresh paths through the brown winter muck, pick up bits of trash you forgot were buried under all that ice and snow, decide what new seeds to plant and where. You've been told your soil is rich—much richer than you thought—and now you are sure that with time and attention and a lot of gritty work, you can grow almost anything. You roll up your sleeves and take stock. What habits of mind will you dig up and toss on the compost heap? What mental skills and emotional states, what beliefs about yourself and the world will you choose to cultivate?

Little more than a decade ago, the physical landscape of our minds was perfectly invisible to us and, for all we knew, as fertile and productive as it was ever going to get. Even if we were aware of our thoughts, ideas, and emotions, we had no way of watching the neural activity associated with mental phenomena arise, do its thing inside our heads, and pass away. We had no way of watching that activity actually alter and strengthen our neural networks. Now, thanks to powerful new imaging tools like functional MRI (fMRI) and positron emission tomography (PET), we can watch the organ of the mind in action, and what we see is exhilarating: The brain has the capacity to heal, grow, and change itself in ways that before were thought impossible.

Conventional scientific wisdom used to paint a starkly different picture of the adult brain, one in which its physical structure was essentially immutable. By the age of three, the story went, most neural networks were in place, and by late adolescence, our temperament—our baseline chemical state of happiness or irritability—was thought to be fixed. If we had always been a sunny kid, our outlook would probably tend toward the golden for the rest of our lives, but for those of us born and raised on the dark side of the moon, we would probably always struggle with negative emotions like anxiety, sadness, and aggression. Compounding the depressing picture was the conviction that, were we to lose nerve cells through disease, aging, or injury, there was very little point in ever wishing them back.

Now we can watch our brains on-screen, healing and adapting to challenges, and we see that our genes and early experiences absolutely *do* influence our cognitive and emotional makeup in important ways, and that they absolutely *don't* get to dictate who we become. This previously unappreciated flexibility and trainability of neural pathways is termed “neuroplasticity,” and it has transformed modern neuroscience into an intensely optimistic field where researchers seek new diagnostic techniques and therapies for patients recovering from structural damage and chemical imbalances due to traumatic brain injury, stroke, Alzheimer’s disease, emotional disorders, drug addiction, and chronic pain. Research into neuroplasticity isn’t just revealing how we can heal brain injuries and sharpen our wits, but also how we can strengthen key neural pathways to become happier, kinder, less fearful, and more effectual merely by changing the way we perceive the world and our reactions to it.

The idea that humans are especially resilient creatures isn’t new. Aristotle, for one, thought that the brain’s chief biological role was to cool the heart, which he took to be the true physical seat of thought, reason, and emotion. The brain “tempers the heat and seething of the heart,”¹ the great philosopher wrote, and because “the heat in man’s heart is purest,”² humans require much bigger brains than beasts. We are the wisest, the best tempered of animals, he conjectured, because our brains are big enough to cool our hot, hot blood.

Our knowledge about the brain’s regulatory role has evolved since Aristotle’s time, but there is a sense in which he got it exactly right. Images of the brain recovering from emotional disorders, traumatic memories, and addiction show that this remarkable organ can, in fact, “cool the heart.” The self-regulating brain can alleviate the intense physiological effects of primal emotions like anger and fear, and in doing so, it can heal emotional damage and protect the body. We may even one day learn to cure the excruciating cravings that keep many of us locked in cycles of addiction by consciously modulating activity in particular areas of the brain. It seems that we’ve always instinctually known that we are born to be highly adaptable—that we are gifted with extraordinary abilities to heal and change in the face of adversity—and now we are taking the pictures to prove it.

Cutting-edge imaging research also holds the promise of providing new diagnostic and therapeutic options for patients suffering from states of impaired awareness or—most harrowingly—from awareness without any ability to communicate with the outside world. A patient’s thoughts might be observed on-screen in ways that could be understood by others—an exciting possibility for families and friends who spend months or even years at the bedside of a loved one recovering from a brain injury. At one heartbreaking extreme, of course, are the patients who never recover any meaningful level of awareness. Stem-cell researchers are working hard to grow functioning neurons in the laboratory, but until such research bears therapeutic fruit, there are certain severe brain injuries—global neuronal loss due to prolonged oxygen deprivation, for example—that simply cannot be repaired.

Standard bedside tests for consciousness have remained largely unchanged for 30 years, as have the painful ambiguities that can accompany end-of-life decisions. Brain-imaging technologies may ease the agony of some of these complex choices by enhancing our understanding of the neural correlates of awareness. Pictures of the brain responding to the world may one day become a standard tool to clarify when medical interventions are working to extend meaningful life and when they are inappropriately and painfully prolonging death.

New imaging tools also mean new hope for age-related cognitive decline. Functional MRI, PET, and a revolutionary imaging substance called Pittsburgh Compound-B (PiB) have revealed that Alzheimer’s disease attacks different parts of the brain than those affected by normal aging, and that some brain systems, including some forms of memory, are left intact by Alzheimer’s. It is possible that these undamaged systems may be trained to help people afflicted with the disease to function better. And for those of us with a few million miles on the brain, there is more to be excited about: Research into new diagnostic methods may help catch the debilitating disease in its earliest stages (when drugs and other forms of therapy might be most effective), while other studies show that certain kinds of mental training can relieve the effects of “normal” age-related memory decline.

Tantalizing pictures of the brain are also emerging from the field of neurotheology, a branch of learning that seeks connections between spiritual experiences and mental activity. Neuroscientists have scanned the brains of spiritual practitioners as diverse as Tibetan Buddhists and Franciscan nuns, and have found striking similarities in their brain activity when they are in states of “higher consciousness”—states in which people stop sensing a separation between themselves and the world, in which their minds feel limitless, expansive, and in touch with God or spiritual insight. Researchers are also identifying neural pathways for spiritually significant mind states like empathy, compassion, and forgiveness, showing not only that prosocial emotions are skills that can be perfected through training, but that practicing them makes our brain circuitry more positive and responsive in ways that could be used to prevent depression and other mood disorders, bullying and violence, and even physical damage inflicted by our own negative internal states.

Pictures of the Mind looks at images across the full spectrum of consciousness—from impaired, to healthy, to “higher”—and at what they tell us about the brain’s extraordinary capacity to heal after illness and injury, to adapt to new challenges, and to retrain itself in ways that can make us happier, healthier people, more attentive to our own needs and to the needs of others. This deepening knowledge about the organ of knowledge is transforming our basic understanding of the “self” from a static and constricted entity to a vast and productive landscape—the ideal ground in which to cultivate conditions for well-being.

1

Life, death, and the middle ground

The last thing you feel is the brute force of a head-on collision. The paramedics arrive at the scene to find you unconscious, a victim of massive head trauma in a devastating car accident. They rush you to the nearest emergency room, where doctors do everything they can to stem the bleeding and limit the damage to your brain.

Your loved ones arrive at the hospital, and they are told to prepare for the worst. Only time and a battery of neurological tests will reveal the true nature and severity of your injuries. You spend several days in a coma, and then, to the great relief of your family and friends, you open your eyes. Everyone close to you rejoices. They take this development as a sign of recovery—that you can see them, hear them, know that they love you. But the doctors caution that it is too early to know if you will ever recover awareness of your surroundings. Their bedside tests indicate that so far, you have not.

You wake up and fall asleep just like a healthy person. This encourages the people who love you, but it does not prove awareness. Sleep cycles are controlled by your brain stem—the most primitive part of your brain—not by regions involved in conscious perception or thought. Over the next several months, you consistently fail standard neurological tests designed to establish whether you are a thinking, feeling, and aware person. You show no overt behaviors that could be read as willed, voluntary, or responsive. Your doctors see no reason for hope. After five months, they diagnose you as persistently vegetative.

Your case, it turns out, is extraordinary, and—quite harrowingly—you are the only person who knows it. You are, in fact, fully aware of yourself and your surroundings, but you are incapable of

making any purposeful movements at all. You cannot even blink your eyes on command. It is the stuff of nightmares—trapped inside a body that you cannot control. Without tools to communicate your thoughts or feelings to loved ones, doctors, or nurses, you feel utterly terrified and alone, cut off from the world. You have no way of knowing whether anyone will ever detect that your mind is still alive, feeling the pain of total isolation.

Can such a catastrophic fate exist? It can, and it has in rare cases, say researchers who are working to scan the brains of patients diagnosed as vegetative.

In July 2005, a 23-year-old English woman was critically injured in a car accident. For a full five months she failed clinical tests of consciousness and her doctors declared her vegetative. Not until half a year after her accident—when researchers in Cambridge, England selected her to take part in a study of brain activity in vegetative patients using state-of-the-art functional magnetic resonance imaging (fMRI)—was her surprising brain activity discovered.

Picturing awareness

MRI technology uses an extraordinarily powerful magnetic field (often up to 30,000 times stronger than the earth's magnetic field) to align excited water molecules with—or against—the direction of the force. The water molecules absorb or transmit radio waves, producing a pattern detected and analyzed by a computer. Structural MRIs have been producing high-resolution, two- and three-dimensional images of the brain since the 1980s.

Functional MRI scanning, first developed in the early 1990s, has been refined and applied at an astonishing pace. The technology uses an MR signal to measure blood-flow changes by recording shifts in blood-oxygen levels. When activity in a certain part of the brain increases, so does the need for fresh oxygen. Blood rushes in, causing the MR signal to increase. In this way, fMRI technology can reveal which parts of the brain are working and under what circumstances.

The young English patient was placed inside an fMRI scanner, and something remarkable happened. When she heard spoken sentences, and then acoustically matched but meaningless noise

sequences, her brain was able to tell them apart, lighting up in telltale language-processing patterns in response to the meaningful sentences.

Lead investigator Adrian M. Owen and the rest of the British and Belgian researchers studying her case were careful to point out that these patterns by themselves were not indisputable evidence of awareness. Studies of “implicit learning and priming,” they emphasized in their report, “as well as studies of learning during anesthesia and sleep, have demonstrated that aspects of human cognition, including speech perception and semantic processing, can go on in the absence of conscious awareness.”¹

But then the truly startling result: Asked to respond to mental imagery commands—first, imagining herself playing tennis, and then picturing herself walking through the rooms of her home—her brain responded instantly and sustained the mental “work” for a full 30 seconds. On screen, her patterns of mental activity were measured by blood traffic to movement and imagery centers in her brain and looked just like a healthy person’s.

This extraordinary result led the neuroscientists studying her case to conclude that she was “beyond any doubt...consciously aware of herself and her surroundings.” Next to brain scans of 12 healthy volunteers, reported Dr. Owen, “you cannot tell which is the patient’s.”² And six months later—one year post-accident—she was able to follow a mirror intermittently to one side, thus joining a relatively new category of patients described as “minimally conscious.”

Dr. Owen and his co-investigators have faced intense criticism from fellow neuroscientists who believe that the findings were overstated—that the fMRI results cannot be deemed clear evidence of purposeful mental activity. The crux of detractors’ arguments is the idea that words presented to the patient in the imagery tasks—words like “tennis” and “house”—could have triggered her mental response even in the absence of awareness.

Not so, said Owen and colleagues in their spring 2007 response in the journal *Science*. Such automatic changes in the absence of conscious awareness “are typically transient (i.e., lasting for a few seconds) and, unsurprisingly, occur in regions of the brain that are associated with word processing. In our patient, the observed activity was not transient but persisted for the full 30 [seconds] of each

imagery task.... In fact, these task-specific changes persisted until the patient was cued with another stimulus indicating that she should rest. Such responses are impossible to explain in terms of automatic brain processes.” What is more, her responses were observed not in the word-processing centers—as would be expected in an unconscious patient—but in “regions that are known to be involved in the two imagery tasks that she was asked to carry out.”³

Psychologist Daniel Greenberg proposed the following test of whether the patient had made a conscious decision to cooperate: What would happen, he asked, if investigators “presented a similar noninstructive sentence such as ‘Sharleen was playing tennis?’”⁴ Owen and colleagues addressed Greenberg’s question by prompting a healthy volunteer with these sorts of noninstructive statements, and the results were persuasive: No activity was observed in any of the brain regions that had been triggered in the patient or healthy volunteers when they were performing the mental imagery tasks. This result, the researchers argued, reaffirmed their original conclusion that the patient was knowingly following instructions, despite her diagnosis to the contrary.

A rare mistake?

The implications of the discovery are haunting. How many patients currently labeled vegetative might show similar patterns of mental activity on an fMRI scan? There are an estimated 25,000 to 35,000 vegetative patients in the United States alone.⁵

Nicholas Schiff, a leading American researcher on impaired consciousness, says that while the study showed “knock-down, drag-out” proof of awareness in this patient, it is unclear “whether we’ll see this in one out of 100 vegetative patients, or one out of 1,000, or ever again.”⁶ Most neuroscientists are of the opinion that the vast majority of vegetative cases would not show the complex mental activity that the young English woman did. Many of these patients—Theresa Schiavo among them—have suffered extreme oxygen deprivation and have lost a massive number of neurons. Steven Laureys, director of the Coma Science Group at the Cyclotron Research Center at the University of Liège in Belgium, reports that his team has “not observed any similar signs of awareness in functional scans of more than 60 other vegetative patients studied at the University of Liège.”⁷

Dr. Laureys coauthored the imaging studies with the young English patient, and he notes that even for experts in impaired consciousness, “the vegetative state is a very disturbing condition. It illustrates how the two main components of consciousness can become completely dissociated: wakefulness remains intact, but awareness—encompassing all thoughts and feelings—is abolished.”⁸

The chance of recovery is greater for victims of a traumatic brain injury like the young English patient, whose injuries are severe but localized. An estimated one-half of all patients who are unconscious due to traumatic injuries—often the victims of car accidents—regain some awareness within a year, whereas only about 15 percent of those with brain damage due to oxygen starvation recover any awareness within the first three months (and very few do after that). A study of 700 vegetative patients in 1994 showed that no patients with injuries from oxygen deprivation recovered after two years.⁹

“One always hesitates to make a lot out of a single case, but what this study shows me is that there may be more going on in terms of patients’ self-awareness than we can learn at the bedside,” said Dr. James Bernat, professor of neurology at Dartmouth Medical School. “Even though we might assume some patients are not aware, I think we should always talk to them, always explain what’s going on, always make them comfortable, because maybe they are there, inside, aware of everything.”¹⁰

Kate Bainbridge from Cambridgeshire, England, agrees. She believes that she, too, has much to owe Dr. Owen’s brain imaging research. She was 26 years old when she succumbed to a viral infection that caused severe brain inflammation, leaving her vegetative for six months according to standard bedside tests. Dr. Owen had begun using scanning technology—in Kate’s case, positron emission tomography (PET)—to investigate patterns of brain activity in patients diagnosed as vegetative. A PET scan takes a biologically active chemical like glucose, tags it with a detectable radioisotope, and records its uptake by active brain cells.

Dr. Owen showed Ms. Bainbridge photographs of her family, and he saw that she recognized them when facial-processing centers in her brain ignited on-screen. When she was shown nonsense images with similar colors, these regions of her brain lay dormant. Dr. Owen

performed additional PET scans over the coming months, and they showed that she was becoming more aware all the time.

“Not being able to communicate was awful—I felt trapped inside my body,” Kate said. “I had loads of questions, like ‘Where am I?’, ‘Why am I here?’, ‘What has happened?’ But I could not ask anyone—I had to work it all out.”¹¹ She formed nightmarish theories to try to make sense of it all. “I thought I was in prison and I had forgotten how to move.”¹²

But the PET scans changed all that, she said. “They found I was there inside my body that did not respond.”¹³ She credits the scans for hastening her recovery, for giving her hope, and for encouraging others to interact with her. It took two years before she regained full consciousness. Now she uses a wheelchair, but she can communicate using a keyboard and she can read, use the computer, and play board games without help.

Her parents agree that Dr. Owen’s discovery was a critical piece of news. “The scan meant an enormous amount to us,” her father said. After the test, “the doctors were able to tell us for the first time that Kate’s brain was processing things. That was a big breakthrough and it meant when we were doing things with her—talking to her, showing her pictures, writing her notes—we felt, even if she didn’t understand, her brain was processing things. We realized something might be there to help her to cope with this horrendous experience she was going through.”¹⁴

When she was told the news that the Cambridge team had discovered what was apparently normal brain activity in another “vegetative” patient, Ms. Bainbridge observed, “I think the work Dr. Owen is doing is so important. I can remember how awful it was to be like I was. It really scares me to think what could have happened if I hadn’t had the scan.”¹⁵

When hope is in vain

The journal *Science*, when it published the remarkable fMRI findings, cautioned that they must not be taken as typical. The editors included a special note in their press release about the study, mentioning the controversial Theresa Schiavo case and stressing that the

new research “should not be used to generalize about all other patients in a vegetative state, particularly since each case may involve a different type of injury.”¹⁶

What about Theresa Schiavo and her heart-wrenching case? Few end-of-life stories have polarized a country the way hers did, and some who followed it might wonder if the results of this new study call her diagnosis as permanently vegetative into question. Was there ever any reasonable hope for Theresa’s recovery?

Decidedly not, say neuroscientists asked to comment, noting that her brain was deprived of oxygen for much too long. By the time paramedics arrived to resuscitate her heart and breathing, her brain was already severely, irreparably damaged. All seven board-certified neurologists who examined her agreed that she was permanently vegetative—that the thinking, feeling part of her brain had died. “As such,” says neurologist Eelco Wijdicks of the Mayo Clinic College of Medicine, “she could never have recovered to an independently functioning human being, able to care for herself.”¹⁷

Despite consensus among neurologists who examined her, Ms. Schiavo’s health was described a number of ways—many of them erroneous—as the public debate raged around removal of her life support. Some neurologists near the end of her life suggested that she might be minimally conscious, whereas other commentators described her as brain dead or, at the other end of the cognitive spectrum, as a victim of locked-in syndrome (LIS), a condition in which there is severe damage to the brainstem but the cerebral cortex is unaffected. A person with LIS can think and feel emotion just like a healthy person, but cannot move or communicate except by blinking.

What role did brain scans play in her diagnosis? Dr. Ronald Cranford, who examined Theresa in 2002, performed a computed tomography (CT) scan of her brain. CT technology takes a series of two-dimensional x-ray images and compiles them, through computer algorithms, into three-dimensional images.* Dr. Cranford reported

* The CT scanner’s existence is thanks in part to the British musical group The Beatles, as their impressive record sales enabled their label, EMI Music Publishing, to fund the research of one of its inventors.

that the scan showed little else than scar tissue and spinal fluid. He also performed an electroencephalogram (EEG), a diagnostic test to record electrical impulses (brain waves) associated with mental activity. The EEG showed no sign of life in the thinking parts of her brain.

“It’s totally flat—nothing,” Dr. Cranford said, “and this is very unusual. The vast majority of people in a persistent vegetative state show about 5 percent of normal brain activity.”¹⁸

The autopsy report, released in June 2005, backed the neurologists’ diagnosis. “This damage was irreversible,” the medical examiner said of the injuries to her brain, which had shrunk to half its normal size. “No amount of therapy or treatment would have regenerated the massive loss of neurons.”¹⁹

A spectrum of awareness

Even if the young English woman’s story proves a rare case, it has prompted concern over whether standard bedside tests for the vegetative state are reliable and whether the boundaries between states of consciousness are clear at all.

The persistent vegetative state (PVS), as we currently understand it, lies on a continuum of impaired brain function. Though neither comatose nor brain dead, vegetative patients are unaware of themselves and their surroundings; they are alive without consciousness. They can wake and fall asleep, but they cannot communicate or respond to commands in a meaningful way. The thinking, feeling part of the brain (the cerebral cortex) no longer functions, but the more primitive part of the brain governing reflexes (the brainstem) still operates. Isolated areas in the cortex may still show activity, but they are disconnected from parts of the brain necessary for conscious perception.

“There are islands of activity in a sea of silence,”²⁰ says Steven Laureys, who has taken PET scans of diverse states of awareness in the hopes of identifying regions in the cerebral cortex—and connections among these regions and other parts of the brain—that may prove crucial to maintaining the experience of consciousness.

Vegetative patients like Theresa Schiavo are often mislabeled as comatose or brain dead, though their brainstems are still fully operative, allowing their hearts and lungs to work and producing sleep-wake

cycles. A comatose patient lingers in a state of profound unconsciousness from which she cannot be roused—even by powerful stimulation—whereas brain death entails total and permanent loss of all brain function and is one of the medical and legal definitions of death. Patients who are brain dead can no longer breathe for themselves, and their hearts will stop beating if they do not receive oxygen from mechanical ventilation. Despite these significant distinctions, a surprising 1996 survey published in the *Annals of Internal Medicine* revealed that almost half of U.S. neurologists and nursing home medical directors believed that patients in a vegetative state could be declared dead.²¹

Current diagnostic guidelines allow patients to be declared permanently vegetative after one year if they have suffered traumatic brain injury (like the young English patient) or after six months if they have suffered brain injury due to oxygen deprivation (like Theresa Schiavo). Rarely, people with oxygen-related brain damage have regained consciousness after being diagnosed as permanently vegetative, but all of those patients recovered within two years. In a few astonishing cases, vegetative patients with traumatic brain injuries have regained consciousness much later. Terry Wallis, an Arkansas mechanic, recovered awareness in 2003, more than 18 years after a serious car accident. Mr. Wallis, many neurologists now believe, would have been more accurately described as “minimally conscious.”

A new class of consciousness

The past few years have seen the emergence of a controversial new category of impaired consciousness, the minimally conscious state (MCS). The term was first used in 2002 to describe people who previously would have been diagnosed as vegetative, but who can track movement with their eyes and may respond intermittently. Eelco Wijdicks of the Mayo Clinic describes MCS as “the most severe form of neurological disability in a conscious patient.”²²

Neurologists agree that it is vital to be able to distinguish between MCS and PVS in a patient, though many are still uncertain if MCS covers a single condition or a wide range of disorders. The diagnostic criteria are “difficult to define,” says Wijdicks, “and the boundaries are uncertain (how minimal and how maximal?).”²³

An estimated 100,000 Americans exist in this state of intermittent awareness, and some do recover fully. “It took years to get some agreement on the definition,” says neurologist Nancy Childs of the Healthcare Rehabilitation Center in Austin, Texas, “and it’s only now getting some acceptance, but we’ve known for years that there was this other group.”²⁴ In the early 1990s, studies designed by Dr. Childs and Dr. Keith Andrews of London’s Royal Hospital for Neurodisability discovered signs of awareness in more than one-third of patients who had originally been diagnosed as vegetative.

Brain scans have figured highly in defining the new diagnosis. A landmark study by Joy Hirsch of Columbia University and Nicholas Schiff of Cornell University’s Weill Medical College used fMRI scans of two minimally conscious patients to examine neural characteristics of the state. During the scan, the investigators played recordings of close family members talking about familiar events in the patients’ lives.²⁵ What Hirsch and Schiff found shocked them: The minimally conscious patients showed mental activity similar to healthy volunteers in response to the meaningful stories—though they showed less activity compared to healthy brains when narratives were played in reverse (and thus were linguistically meaningless).

“It was haunting,”²⁶ Hirsch recalled when she discussed the findings. Results like these, though not ironclad proof of awareness, suggest that there may be cognitive life in patients who cannot respond to simple commands or communicate reliably.

Silent witness

Nick Chisholm was a gifted 23-year-old athlete—in love with sports and life—when he took a devastating hit on a New Zealand rugby field. His vision went blurry and he felt sick immediately, but he chalked his symptoms up to a minor concussion. When he came off the field, he asked his coach to put him back in after a mere ten minutes’ rest—but then he collapsed and paramedics rushed him to the hospital.

Three days later, it was still unclear what had happened to Nick, but he seemed to be recovering well. The doctors were going to let him go home. Then he nearly collapsed again in the hospital shower,

and for the next six days suffered a series of seizures that ultimately left him paralyzed and unable to speak. A battery of tests—which felt like “all the tests known to man,”²⁷ as Nick reports it—revealed that he had suffered several strokes due to a dissection of his vertebral arteries. One of the strokes was so massive that it effectively annihilated his brain stem, severing the connections between his higher brain and the rest of his body.

After that horrific accident in 2000, Nick was diagnosed with locked-in syndrome (LIS), an extremely rare condition in which a person’s conscious mental life and senses remain intact, but in which he is unable to move or to use his body to communicate (except by shifting his eyes or by blinking). LIS can result from a sudden injury like Nick’s, or it can be due to progressive degeneration of motor neurons in the devastating neurological condition amyotrophic lateral sclerosis (ALS).

It took some time—an excruciating stretch for Nick—before he was properly diagnosed. The doctors didn’t know that he was aware and listening when they told his mother that he would probably die, and then offered her the option of withdrawing life support. It was Nick’s family that guessed that he wasn’t comatose at all, but instead was fully conscious and able to follow every word that was said. When asked by TV New Zealand several years later to share the most frightening thing he heard during that time, Nick did not hesitate to answer that it was the doctors speaking of turning off his life support machine.²⁸

“Nick’s mother and his girlfriend pleaded with the medical staff to realize that he was aware of what was happening,”²⁹ reports medical ethicist Grant Gillett, who co-wrote a piece with Chisholm for the British medical journal *BMJ*. “When the clinicians appreciated that the diagnosis was locked-in syndrome, the climate of care changed.”

Misdiagnosis of LIS is tragically common, as it is often mistaken for the vegetative state or even coma. As happened with Nick, more than half of LIS cases are identified by family members rather than by physicians or nurses, because family members tend naturally to be more attuned to the patient’s needs and to read signs of a conscious presence. A 2002 survey of 44 LIS patients found that diagnosis took

an average of two-and-a-half months,³⁰ and in some harrowing cases, it took as long as six years. Even after family members catch on, they may still have trouble convincing the attending physicians that their loved one is fully conscious.

In recent years, brain scans have shed terrifying light on the acute experience of LIS—what it is like to realize that you are conscious inside an unresponsive body without the means to communicate your experience to others. PET scans have shown that glucose metabolism in the brain’s higher regions does not differ significantly in patients with LIS as compared to healthy age-matched controls, supporting the conclusion that their injury is restricted to physical paralysis, and that these patients can, as Laureys and colleagues report, “recover an entirely intact intellectual capacity.”³¹ PET images have also revealed a telling neural signature in acute LIS patients, one that differs strikingly from healthy controls: The amygdala—a primitive part of the brain linked to primal emotions like fear and anxiety—was hyperactive in acute, but not in chronic, LIS patients.

“It is difficult to make judgments about patients’ thoughts and feelings when they awake from their coma in a motionless shell,” say Laureys and colleagues, but in light of the evidently normal metabolism in higher regions of the brain, these researchers hypothesize that the pronounced amygdala activity in conscious patients who had not yet learned to communicate with the outside world “relates to the terrifying situation of an intact awareness in a sensitive being, experiencing frustration, stress, and anguish, locked in an immobile body.” They conclude from this preliminary imaging evidence that medical professionals caring for patients with LIS must adjust their bedside behavior to address states of extreme emotional distress.

We can only imagine, Gillett notes, “the sheer awfulness of hearing others discuss turning off one’s life support.”³² Even after medical professionals knew that Nick was fully conscious and aware of everything unfolding in the room, Gillett says that Nick still “heard things said about his prognosis and his life that paid little regard to what he might have been thinking.” Nick reports that his case manager for New Zealand’s Accident Compensation Corporation said in his presence that even if he did live, he wouldn’t want to anyway, and a specialist told him to get used to the wheelchair, because he would be in one for the rest of his life. In his second year in the hospital, another

specialist told him that whatever gains he had made to date were the only improvements he'd ever see.

Nick begged to differ. "What do they really know? They only know what they read in textbooks," he says, and he characterizes most of his specialists and doctors as "so extremely negative."

In cases of locked-in syndrome, clinicians naturally make mistakes all the time about what a patient is thinking or feeling, Gillett says, because it is a state of consciousness that simply defies our ability to know how it feels to be the other person. "We must make special efforts to reach past the locked-in syndrome barrier and allow the patient to connect with us," he argues. No matter how closely Nick's condition resembles other states devoid of awareness, he must be treated like a whole person, capable of experiencing a complete range of thoughts, feelings, and emotions.

Rather than experiencing cognitive deficits, Nick feels that some of his senses—sight and hearing in particular—have actually been enhanced by his situation. Because of the natural tendencies of people surrounding LIS patients to dwell on everything that has been lost, it is all too easy, Gillett observes, to become blinded to the "ongoing work of 'self remaking' that someone like Nick is doing." To hear Nick speak through his brother (who has learned to interpret for him), it is obvious that despite severe disabilities, Nick is as mentally quick as ever—and that however we choose to define personhood, he hasn't lost it. Before his accident, he thrived on social interaction and on cracking wicked jokes; if anything, those aspects of his mental life have become more nourishing to him than ever.

"I don't think I could've made it this far without the support of my friends, carers, and family," Nick says. After his return from the hospital, Nick was able to regularly attend his old rugby team's games with the help of a good friend, and his injury did not get in the way of his pulling outrageous stunts. (Nick, his brother, and several buddies landed on You Tube, for example, for showing up naked to the polls on election day.) And it is not just family and old friends who keep Nick going socially. "I have met a lot of people since my accident," he says. "Some have become friends; some have become great friends."

By all accounts, Nick's recovery has been remarkable. During his two years in the hospital, he had to exert an enormous amount of effort to make a single sound, but in 2005 he wrote that "I can now say heaps of words, count, pronounce about four carers' names relatively clearly, sometimes stringing some words together when lying down and relaxed." Since this account in *BMJ*, Nick has learned to use a walker for short distances and even to use certain weight machines with assistance, defying specialists who told him that he would never recover any physical skills. (He remembers one specialist who told him that he'd never move or talk again. When Nick returned home from his long hospital stay, the specialist examined him and was taken aback by Nick's progress. He apologized to Nick for his early predictions. "I gave him the finger," Nick reports.)

His recovery has been extraordinary, but not atypical for LIS patients receiving an intense and consistent level of care. A 2003 study followed 14 patients with locked-in syndrome in three rehabilitation centers for periods ranging from five months to six years, and found that early and intensive rehabilitation treatment significantly improved outcomes and reduced mortality rates.³³ Laureys and colleagues have reported that in a study of 95 patients with LIS,³⁴ 92 percent recovered some ability to move their heads, and half recovered limited speech production (single intelligible words). Some patients recovered the ability to make small movements in fingers, hands, or arms (65 percent), and three-quarters recovered the ability to make small motions in their legs or feet.

Will to live

Even for someone like Nick, gifted with a fighting spirit and keen sense of humor, there are the inevitable moments when life feels unbearable. Before the accident, reports one of his best friends, he had "muscles on his muscles, he was happy as hell, he had a beautiful girlfriend. He couldn't have been any better."³⁵ Now Nick says it can be a lonely existence, and he believes that dating and romantic relationships are out of the question. "It would be great," his brother translates, "but able-bodied people struggle getting dates. So I'm stuffed."

He talks of the utter humiliation of his condition—times when he loses control of his bowels in public places, for example. "Believe me,

when you're 30 it's totally degrading," he says. "And nowhere more so than in the public gym, in front of people. It definitely changes my mood extremely quickly when it happens, as you can imagine."³⁶ He admits that he has often thought of suicide, especially alone in his bed at night. Sometimes he wishes that he had died in the ambulance on the way to the hospital—it would have been less frustrating that way—but even if he wanted to commit suicide now, he couldn't do it. "It's physically impossible," he notes—though he has discussed the topic with the people closest to him.

"Yeah, we've talked about it," his brother says. "Nick has said things along the lines of, 'I don't want to live 40 or 50 years in this chair, in this cocoon.' And I can understand that. Who am I to say, in my situation, that he should live his life like that?"³⁷ But even if it were possible to end his life—alone or with help—Nick says it wouldn't matter. "I'm just glad to still be alive—most of the time anyway," he says. "I only live for hope of recovery now."³⁸

Despite the common misperception that LIS patients—given the option—would choose to die, Nick's determination to live fits with the majority sentiment in patients with his condition. "Healthy individuals and medical professionals sometimes assume that the quality of life of an LIS patient is so poor that it is not worth living,"³⁹ say Laureys and colleagues. "On the contrary, chronic LIS patients typically self-report meaningful quality of life and their demand for euthanasia is surprisingly infrequent." Experts in LIS are concerned that uninformed physicians might provide less aggressive medical treatment than might be warranted with particular patients, despite studies showing decreased mortality and improved quality of life with early diagnosis and treatment. Physicians less familiar with the experiences and wishes of LIS patients might even influence the family toward removal of life support without ensuring that everything reasonable has been done to reveal the patient's preferences.

Regardless of what care locked-in patients ultimately request, Laureys and colleagues stress that their autonomy should be considered paramount. "Patients suffering from LIS should not be denied the right to die—and to die with dignity—but also, and more importantly, they should not be denied the right to live—and to live with dignity and the best possible revalidation, and pain and symptom management."

For his part, Nick doesn't want it left up to anyone else to decide whether his life is worth living. When asked by TV New Zealand in 2007 if he considers himself happy, Nick said, "Absolutely. Coming from where I've been, this is absolutely fantastic. I'm probably happier than most able-bodied people."⁴⁰

Speaking without a voice

Nick's tool to communicate with the outside world is a large transparent board with the letters of the alphabet spread across the surface. He spells out each letter of his sentences painstakingly with his eyes, and the person "listening" on the other side of the board must guess which letter Nick is staring at. This goes on until he has spelled out entire sentences—a process Nick describes as "extremely laborious."⁴¹ For a person like Nick—to whom horsing around with his friends is so important—the inability to banter can be excruciating. It is "very difficult (almost impossible)," he says, "to express yourself or be sarcastic."

Speech devices like Nick's board require assistance from other people to transmit anything verbally—including thoughts and feelings, calls for help, and requests for information—a frustrating reality that only compounds the utter dependence of LIS patients upon others. Cases like Nick's, Gillett says, require that we care enough to "rebuild the tools of communication (through interactive technology and massive personal commitment) so that he can begin to live again among us, albeit with severe disabilities."

State-of-the-art patient-computer interfaces, such as infrared eye sensors coupled to on-screen keyboards, are improving the lives of many LIS patients and their caregivers. These devices allow LIS patients the freedom to perform simple, everyday actions the rest of us take for granted, such as turning lights and appliances on and off, communicating by phone or fax, surfing the Web, sending e-mails, and using word processors and speech synthesizers. These devices cost thousands of dollars—sometimes a prohibitive sum for patients whose insurance won't pay for them—but for those patients who can manage the cost, these devices provide unprecedented freedom.

Patients like Nick—with the ability to consciously control their eye movements—would clearly benefit from the independence such

devices afford, but what of patients like the young English woman, who showed signs of consciousness without the ability to control her eyes? For some patients, computer interfaces relying on eye control won't take communication technology far enough. Researchers working with disorders of consciousness welcome the prospect of direct mind-computer interfaces based on fMRI or other functional neuroimaging that could, in effect, read patients' thoughts and emotions, allowing them an active voice in their treatment and in critical life-extending—or life-ending—decisions.

“The beauty of medical and communication-technological progress for patients with severe neurological conditions is that it makes them more and more like the rest of us,”⁴² Laureys and fellow researchers with the Coma Science Group observed in a recent editorial. “As a corollary, we caregivers not only owe them the same respect in terms of their autonomy as all other patients, but we also have to rise to so far seldom attained levels of clarity in matters of life and death.”

The future of consciousness imaging

The British and Belgian team's conclusion that the young English patient is “beyond any doubt” aware has sparked scientific controversy, but neurologists agree on one point: Her remarkable story strengthens the case for the use of fMRI as a diagnostic tool in the absence of external signs of responsiveness.

The concern remains that with time and additional testing, brain scans might prove unreliable and might even raise false hopes in futile cases. But there is widespread optimism that Dr. Owen's claim might be true—that he and his team “have found a way to show that a patient is aware when existing clinical methods have been unable to provide that information.”⁴³

In addition to its potential diagnostic uses, Owen, Laureys, and colleagues believe fMRI could prove therapeutically powerful. The young English woman's demonstrable mental actions, they argue, suggest “a method by which some noncommunicative patients, including those diagnosed as vegetative, minimally conscious, or locked in, may be able to use their residual cognitive capabilities to communicate their thoughts to those around them by modulating their own neural activity.”⁴⁴

A patient's thoughts could show up on-screen in ways that might be understood by others—a heartening prospect for families and friends of patients like Kate Bainbridge and Nick Chisholm, who may spend excruciating months or years hoping and praying for their loved one's recovery. Even if fMRI fails as a communication device, it might ensure that patients receive the most appropriate care for their condition, as soon after their injury as medically possible.

At the other end of the spectrum are patients who, tragically, will not get better. For these patients, high-tech life support maintains their body without promoting meaningful recovery. The arrival of powerful life-extending technologies in the 1960s and 1970s provided new hope for seriously ill and injured patients who might recover with time, but there was a new problem. These machines could, in the words of Supreme Court Justice Antonin Scalia in the 1990 Nancy Cruzan verdict, “keep the human body alive for longer than any reasonable person would want to inhabit it.” Families were faced with the unbearable decision of when, if ever, to withdraw medical care from a loved one.

What parent would not sympathize with the heartache of Nancy Cruzan's father? Nancy—whose car flipped on an icy, deserted road in the winter of 1983 and threw her facedown in a watery ditch—suffered severe brain damage due to oxygen starvation, just as Theresa Schiavo would several years later. Mr. Cruzan, faced with the horrific choice of whether or not to remove his daughter from life support, mourned, “If only the ambulance had arrived five minutes earlier or five minutes later.”⁴⁵

Loved ones face precisely the same agonizing dilemma today. The fMRI scan answered a question for the young English patient's loved ones, a question that torments family and friends at the bedsides of comatose and vegetative patients everywhere. “Can she hear what I am saying?”

In this extraordinary case, the answer appears to be “Yes.”

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